Space Technology Research Grants

Large Payload HIAD Systems: Structural Investigation and Optimization

Completed Technology Project (2015 - 2017)

Project Introduction

This proposal seeks to advance the understanding of full-scale Hypersonic Inflatable Aerodynamic Decelerators (HIADs) in support of NASA's Space Technology Roadmap, TABS element 9.1.4, Deployable Hypersonic Aeroshells. The HIAD system is a low technology readiness level (TRL) space technology that has the potential to deliver the size of payloads that will be required for human missions to Mars. The current state of the art Mars payload delivery is estimated at 1.5 metric tons. However, payloads on the order of 20 to 60 metric tons will be required for a successful human mission to Mars. Upwards of a 40 fold increase in payload mass represents a significant jump from the currently available decelerator technology. The HIAD system consists of multiple, inflatable tori that are strapped together other around a rigid center-body in a cone configuration and are covered with a thermal protection shield. The individual tori consist of a flexible fabric shell with integral axial cords that are rigidified by the inflation pressure. The HIAD system offers considerable benefits from traditional rigid aeroshells including a small storage volume and a mass to area ratio that is not constrained by the size of the launch vehicle. The HIAD system can be effective in thin atmospheres. Work to date has focused on quantifying the structural behavior of HIAD materials, structural components and test-scale HIAD structures, (3 m major diameter). Although engineers have had success modeling the HIAD system at the test-scale, there is still much unknown about how the structure will behave at a full or human-scale, (~20 m major diameter). Scalability remains one of the major technical challenges associated with deployable aeroshells. Design exploration and optimization of human-scale HIAD structures are important next steps in the development of the HIAD technology. A critical component is the development of computationally efficient structural analysis methods. Modeling efforts to date have focused on high-fidelity yet computationally expensive shell-based finite element (FE) modeling. This work proposes to develop computationally inexpensive three-dimensional beam-based FE models to analyze the HIAD system. Since the HIAD consists of multiple, slender, inflatable members, it is a good candidate for beam based FE modeling. The analysis tool will necessarily incorporate both large deformations and nonlinear material constitutive relationships to accurately capture the structural response of the inflatable members. The HIAD system will be modeled with torus and strap elements as well as elements between tori to capture tori interaction. The material and component level models will be validated with an extensive set of existing test data. Developing a beam-element-based simulation technology will allow for exploration of optimal HIAD configuration and will greatly enhancing our understanding of the HIAD structure. The use of optimization methods to explore the feasible design space can often lead to non-intuitive designs and configurations. For example, exploring non-axisymmetric designs or designs incorporating a radial spoke configuration from the center body to the outer torus are configurations that have not been considered, but are possible feasible alternatives that can be readily explored with the methods envisioned. Development of a comprehensive beam based FE tool will facilitate

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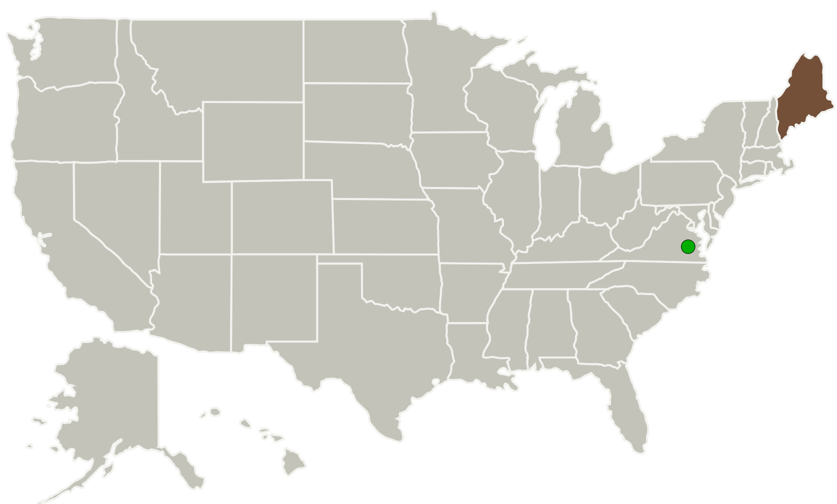
the efficient exploration of the human-scale HIAD design space and will increase our understanding of the behavior of the low-TRL HIAD space technology. Major technological challenges associated with deployable aeroshells remain. In order to further the technology and ensure that the HIAD system will one day be capable of accommodating the requirements of a crewed mission to Mars, further investigations into the behavior of the system at the full-scale are required.

Anticipated Benefits

Development of a comprehensive beam based FE tool will facilitate the efficient exploration of the human-scale HIAD design space and will increase our understanding of the behavior of the low-TRL HIAD space technology.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
University of Maine	Lead Organization	Academia	Orono, Maine
Langley Research Center(LaRC)	Supporting Organization	NASA Center	Hampton, Virginia

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

University of Maine

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Bill Davids

Co-Investigator:

Andrew G Young

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Primary U.S. Work Locations

Maine

Project Website:

https://www.nasa.gov/strg#.VQb6T0jJzyE

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**

1	2	3	4	5	6	7	8	9
Applied Research			Development			Demo & Test		

Technology Areas

Primary:

- TX12 Materials, Structures, Mechanical Systems, and Manufacturing
  └ TX12.3 Mechanical Systems
    └ TX12.3.1 Deployables, Docking, and Interfaces

Target Destination

Mars